Technical Paper 335

IMAGE INTERPRETER SCREENING PERFORMANCE AS AFFECTED BY RESOLUTION, PRESENTATION RATE, AND SCALE

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BATTLEFIELD INFORMATION SYSTEMS TECHNICAL AREA

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study measured performance levels of image interpreters, using both direct viewing and viewing with magnification, to screen 70mm photographic imagery moving at six different rates and varying in scale and resolution. The resolution of the imagery was varied to simulate imagery obtained with different transmission bandwidths. The results were as follows.

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20. Abstract (cont)

1. There is little loss in screening accuracy at any level of resolution and/or magnification for frame presentation rates of 6.0 to 1.5 sec/frame with the 1:2,000 scale imagery and 6.0 to 2.0 sec/frame for the 1:4,000 scale imagery.

2. In general, the poorer the image resolution, the lower the screening accuracy.

3. For constant display format and image resolution, screening accuracy is significantly greater for the larger scale display.

4. Two-power optical magnification of the photographic imagery resulted in a decrease in screening accuracy. Increasing viewing time for magnified imagery by a factor of four so that the incremental area viewed per second was equated for direct and magnified viewing resulted in no significant difference between the two viewing conditions.

Tradeoffs are possible between and among the factors of scale, presentation rate, and resolution.

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BATTLEFIELD INFORMATION SYSTEMS TECHNICAL AREA

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FOREWORD

The Battlefield Information Systems Technical Area of the Army Research Institute (ARI) is concerned with the human resource demands of increasingly complex battlefield systems used to acquire, transmit, process, disseminate, and utilize information. This increased complexity places greater demands upon the operator interacting with the machine system. Research in this area focuses on human performance problems related to interactions within command and control centers as well as issues of system development. Research subjects include software development, topographic products and procedures, tactical symbology, user-oriented systems, information management, staff operations and procedures, decision support, and sensor systems integration and utilization.

One increasingly important source of intelligence information on the modern battlefield is telemetered imagery from remotely piloted vehicles or other sensor platforms. A first step in real- or near real-time exploitation of this information involves screening the many images obtained, so that the limited number of available interpreters can produce timely intelligence. Output of information systems is strongly affected by the interaction of design specifications and human capabilities. Telemetered imagery imposes high demands upon already overloaded tactical communications. One potential solution to this problem is to use low-resolution imagery transmitted by narrow radio bandwidths. Previous ARI research (Technical Paper 213) has found that low-resolution imagery can be used for rapid screening. The present research extended earlier findings, using imagery of known resolution to recommend system design tradeoffs and provide performance data.

Research in the area of sensor systems integration and utilization is conducted as an in-house effort augmented by contracts with organizations selected for their specialized capabilities and unique facilities. The research presented here was conducted by personnel from the System Development Corporation under the program direction of Dr. Abraham H. Birnbaum. Research in this area was responsive to general requirements of Army Project 2J620901A721 and to special requirements of the U.S. Army Assistant Chief of Staff for Intelligence.

Joseph Zeidner

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IMAGE INTERPRETER SCREENING PERFORMANCE AS AFFECTED BY RESOLUTION, PRESENTATION RATE, AND SCALE

BRIEF

Requirement:

To determine the performance levels of image interpreters, using direct viewing and viewing with magnification to screen moving photographic imagery varying in scale and resolution. The variation in resolution simulates imagery obtained under different transmission bandwidths.

Procedure:

Forty-eight image interpreters were randomly assigned to screen four sets of 100-frame rolls containing 1:2,000 and 1:4,000 scale 70mm imagery at one of six film-movement rates under viewing conditions of no magnification and 2-power magnification. Each 100-frame roll contained essentially the same 50 target and 50 nontarget frames; the sequence of target/nontarget frames was randomly determined. Scene content from frame to frame was neither overlapping nor contiguous. For each roll of imagery, the 100 frames were divided into four batches--25 frames per batch--with each batch at one of four levels of resolution: 8, 12, 16, and 24 inches smallest resolvable ground dimension. The resolutions were systematically varied for the four rolls of imagery, so that a subject never viewed a given scene twice at the same resolution.

Two 70mm projectors were modified to permit direct viewing of the imagery. One device, using specially prepared practice imagery, was used for training the examinees to respond at the proper time. Subjects had to indicate which frames contained targets (wheeled or tracked vehicles) and which did not. The other device was used for the experimental runs. Subjects made their responses by actuating a three-position switch, which was wired to a polygraph event recorder. The response tapes were scored for screening accuracy and screening thoroughness.

Findings:

Interpretation of moving 70mm positive photographic imagery for identification of wheeled or tracked vehicles became significantly less accurate with poorer image resolution, faster presentation rates, and reductions in image scale.

In general, the poorer the resolution, the lower the screening accuracy scores.

There was little loss in accuracy generally with presentation rates of 6.0-1.5 seconds per frame for large-scale imagery and 6.0-2.0 seconds per frame for small-scale imagery at all levels of resolution. At faster rates than these, accuracy decreased as rates increased.

Accuracy scores were higher with larger scale imagery (1:2,000, in which the display showed a smaller area of terrain) than with small-scale imagery of the same resolution.

Doubling the size of the image by 2x magnification without changing resolution or scale did not increase accuracy. Unless viewing time was lengthened proportionally (4x) to the increased perceived viewing area, accuracy decreased.

Utilization of Findings:

The factors of image resolution, presentation rate, and scale are of primary importance in determining screening accuracy for 70mm telemetered image displays for wheeled or tracked vehicles.

Tradeoffs which may be acceptable operationally are possible among these factors. For example, screening accuracy of poor resolution displays can be enhanced by lengthening presentation rate by .8-2.0 seconds per frame. Increasing viewing time more than 2.0 seconds per frame does not increase screening accuracy. Accuracy is also improved by increasing the scale of the ground station display so that the imagery covers a proportionately smaller area of terrain, even though the smallest resolvable ground dimension is unchanged.

IMAGE INTERPRETER SCREENING PERFORMANCE AS AFFECTED BY RESOLUTION, PRESENTATION RATE, AND SCALE

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BACKGROUND

The resolution of transmitted imagery depends upon the size of the radio bandwidth used to transmit the imagery. For a constant transmission time, bandwidth required is directly proportional to the square of the resolution needed. When near real-time interpretation at a ground facility is desired, the imposition of the demands of high-quality imagery transmission on an already crowded radio band can prove troublesome. To allow transmission of high-quality imagery as fast as possible, all the available bandwidths may have to be used, to the detriment of other kinds of radio communications designed to operate within those frequencies. One solution to this problem may be initial use of low-resolution imagery (transmitted at narrow bandwidth), which can be screened rapidly followed by retransmission, at higher resolution, of frames selected as containing targets.

The author has undertaken previous work to investigate the potential of rapid screening of low-resolution imagery. A pilot study revealed that moderate success in screening fair-quality moving imagery can be attained with 70mm film movement rates up to 3 in./sec. (or about .8 sec/frame) if the scale is not too small. These results provided guidance for selection of film movement rates used in a second experiment. The second experiment investigated the effects of six film rates (.8, 1.0, 1.5, 2.0, 4.0, and 6.0 sec/frame), four levels of relative resolution, and two levels of scale (1:2,000 and 1:4,000) upon success of screening 70mm imagery for wheeled or tracked vehicles.[1] Unfortunately, in the second experiment the precise resolution of the imagery in terms of smallest resolvable ground dimension at each resolution level was unknown; therefore the present experiment was necessary.

OBJECTIVES

This study was undertaken to assess the feasibility of using low-resolution imagery for rapid screening. The independent variables used were the same as those previously described for the second experiment, but the results of this experiment are more definitive because the smallest resolvable ground dimensions were known for the different

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[1] Lepkowski, J. R. Study of Near Real-Time Screening Performance. 1: Scale, Resolution, and Presentation Rate. ARI Technical Research Note 213, August 1969. (AD 698455)

resolution levels. In addition, in this experiment each scale was viewed under 2-power (2x) magnification to obtain measures of the effect of magnification on screening performance.

In summary, the objectives of this study were to determine the effects of level of resolution, movement rates, scale, and magnification on image interpreter performance in screening 70mm imagery for wheeled or tracked vehicles.

PROCEDURE

Experimental Sample

Forty-eight enlisted men who recently graduated from the Image Interpretation Course at the U.S. Army Intelligence School at Fort Holabird, Md., participated in the study as examinees. These men were members of four successive graduation classes during January and February 1969. Half were between 19 and 20 years of age, and the rest were between 20 years, 1 month, and 26 years, 8 months.

Research Design

The task in this study was to screen each frame for wheeled or tracked vehicles. Each frame required a "target" or "nontarget" response. The presence of at least one vehicle was sufficient to classify a frame as a target frame.

The experimental design permitted all combinations of the three independent variables of interest to be tested. The independent variables were

1. Scale in four levels: 1:2,000, 1:4,000 viewed with no magnification and at 2x magnification;

2. Film movement rate in six levels: 6.0, 4.0, 2.0, 1.5, 1.0, and .8 sec/frame; and

3. Imagery resolution in four levels at each scale level: where the smallest resolvable ground dimensions (SRGD) are approximately 8, 12, 16, and 24 inches each.

The dependent variables were

1. Screening accuracy and

2. Screening thoroughness.

Screening accuracy was defined as the sum of frames correctly classified as target frames and nontarget frames. In terms of the following diagram, screening accuracy = A + D.

		Stimulus frame	
		Target	Nontarget
Response	Target	A Correct	B Incorrect
	Nontarget	C Incorrect	D Correct

Screening accuracy = A + D.

Screening thoroughness was defined as the number of frames responded to, of the 100 frames presented in each run; in terms of the diagram,

Screening thoroughness = A + B + C + D.

<u>Experimental Materials</u>

<u>Imagery</u>. The imagery used in this study met the following criteria.

1. Target types used--wheeled and/or tracked vehicles (trucks, trailers, tanks, automobiles, bulldozers, cranes, road graders, front-end loaders, armored personnel carriers, and a universal tractor);

2. A range of target densities per frame (zero to about a dozen);

3. A wide range of foliage cover (0% to about 90%);

4. Enough imagery to provide 50 target frames and 50 nontarget frames in 70mm format;

5. Scales about 1:2,000 and 1:4,000;

6. Absence of manmade objects other than vehicles and roads; and

7. Resolution, the smallest resolvable ground dimension (SRGD), of the imagery--must be known and be relatively consistent at the selected levels.

The procedure used to produce the imagery meeting the above criteria is described in Appendix A. This procedure was used to produce eight sets of frames that were almost identical in target content and format size but differed in scale (i.e., scale 1:2,000 and 1:4,000) and resolution (SRGD's of 8, 12, 16, and 24 inches). Due to the constant format size, each large-scale frame displayed only one-quarter of the terrain covered by the equivalent small-scale frame.

So that all examinees could contribute to the screening accuracy scores for all levels of resolution and scale, the eight sets of imagery were cut into batches containing 25 frames. The batches were respliced together into eight sets of imagery, so that each set was at one scale and contained all levels of resolution. For example, in a given set the first 25 frames might be the highest resolution, the second 25 frames the third-highest resolution, the next 25 frames the second-highest resolution, and the last 25 frames the lowest resolution.

The testing schedule shown in Table 1 was replicated for each of the six film movement rates, eight subjects being used in each of the six replications. Each subject viewed four sets of 100 frames, each set differing in the combination of scale and magnification but containing essentially the same imagery. The capital letters in the body of Table 1 represent the display scale for each set of 100 frames: small (S), small-magnified (SM), large (L), and large-magnified (LM). The order in which the different scales were used is indicated in Table 1 by the order of the capital letters from left to right. Within each set of 100 frames, the 25 frame batches for each resolution are represented in the body of Table 1 by the lowercase letters a, b, c, and d. Highest resolution is indicated by a, and lowest resolution by d. The serial order in which the different resolutions appeared within a set of 100 frames is indicated by the order of the lowercase letters. The resolutions were systematically varied for the four rolls of imagery so that a subject never viewed a given scene twice at the same resolution. Thus, examinees 1 and 2 were presented with the different scales in the sequence S, L, SM, and LM. Within the set of 100 frames for the first scale, S, the order of presentation for resolution was a, c, b, d.

Testing and Recording Devices. Two similar sets of display apparatus were employed in the present experiment. Each piece of equipment consisted of a 70mm film projector and a motorized film drive permitting selection of film movement rates ranging from barely perceptible motion to about 3 in./sec. During this study, repeatability of a given rate was obtained with a maximum error of 2%. Oversized reel hubs reduced film movement rate difference between the first 10 and the last 10 of the total 100 frames in each run to less than 1%. Runs at a given movement rate varied by a maximum of 2% from the specified movement rate.

Table 1

Testing Schedule for the Six Different Presentation Rates

(Pairs of examinees)	Scale and resolution			
1 and 2	S acbd	L cbda	SM dacb	LM bdac
3 and 4	L bdac	S dacb	LM cbda	SM acbd
5 and 6	LM dacb	SM bdac	L acbd	S cbda
7 and 8	SM cbda	LM acbd	S bdac	L dacb

The optics were removed from each projector to permit direct viewing of the imagery. Light diffusers were placed between the light source and the film to prevent "hot spots" and to spread the lighting more evenly. The illumination intensity control for each piece of equipment was set to provide approximately 2.45 foot lamberts of backlighting. This light level was the average level preferred by three experienced image interpreters who were free to vary the light intensity while viewing similar moving imagery in a preliminary study.

For both the unmagnified, small-scale and unmagnified, large-scale runs, the projectors were so placed that the examinee could select his own viewing distance. All examinees selected a position between 12 and 15 inches from the imagery. For the magnified-scale runs, the viewing distance had to be fixed at 17.25 inches from the optical center (or principal plane) of the 5-inch diameter, double-convex, 2-power lens to obtain a 2x magnification of the imagery. A mount with padded headrest was attached to the testing equipment to maintain the appropriate viewing distance.

A paper tape record of examinee responses on the experimental run was obtained by use of a polygraph event recorder. One channel of the polygraph indicated the beginning and end of each frame's presentation period. A second channel gave an indication of those frames selected as containing targets and a third channel, those frames not containing targets. Examinees were required to indicate their selection for each frame by actuating a spring-loaded, three-position switch. Flicking the switch to the right indicated that the frame being presented was

selected as containing one or more targets. Flicking the switch to the left indicated that the frame being presented was selected as containing no targets. Examinees used the middle or neutral position for the waiting period between responses.

Technique Used to Motivate Subjects

The examinees were tested in pairs. Each pair was asked to read a one-page "General Background" sheet (see Appendix B), which introduced the matter of radio transmission of photographic imagery and told the subjects what was expected to be learned from the experiment. A discussion period of several minutes followed, to further explain photographic transmission problems and to interest the examinees in the importance of obtaining the desired data. The experimental design was then explained in some detail to show how each pair was assigned to the various sets of conditions but without revealing the set of conditions to which the pair was assigned.

Pretest Training

Since an early or late response to a given frame during the experimental run would be associated by the recorder with the preceding frame or following frame, respectively, instead of the frame intended, some pretest training was needed. One of the two available display apparatus was used as a training machine. A special set of imagery was prepared containing eight target frames (with vehicles which were easily seen) and seven nontarget frames (without vehicles or man-made objects).

At the training machine, each pair of examinees was given instructions in how they were to respond to each frame of imagery. A copy of the Training Instructions appears in Appendix C.

The examinees were assured that if they did not readily see a target on a given frame, that frame was a nontarget frame. The object of this pretest training was not to check the ability of an examinee to detect targets, but rather to teach him <u>when</u> to respond.

Film movement was from right to left. The examinee was told not to respond to a frame until some part of that frame was behind the left edge of the viewing port, which was marked with green.

The margin of the pretest imagery was punch-coded for a pickup switch.[2] The on/off status of this pickup switch was used in conjunction with the position of the Target/No Target switch to produce a red

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[2] With the coding scheme employed, it was also necessary to introduce some blank frames in the run to confuse the examinee concerning the sequence of frames.

light directly below the imagery in the viewing port whenever the correct response was early or late or a misinterpretation occurred. Misinterpretations were rare, and when they did occur, the examinee typically remarked that he recognized making that type of error, or had moved the Target/No Target switch in the wrong direction.

Each examinee was trained with the film movement rate he was scheduled to receive on the experimental machine. Training was accomplished rather quickly where the 4 and 6 sec/frame rates were scheduled. But for the faster rates, especially the .8 sec/frame rate--which required decision/reaction times approaching the psychophysiological limit--several trials, first at slow and then at increasing speeds, were allowed.[3] All examinees were required to give at least two error-free runs at their scheduled rates on the training machine before proceeding with the experimental run.

Experimental Testing

After the training session, each examinee, in turn, was seated at the experimental run machine and given instructions for the experimental testing (Appendix D). The examinee was informed that he was to screen 100 frames of imagery for vehicles (tanks, trucks, trailers, and automobiles, as well as the various types of engineer corps equipment) and reminded of how and when to respond to each frame. He was also informed that there would be no blank frames and no red light to indicate early or late responses. In addition, the examinee was informed that he could expect to see the image quality change periodically.

Scoring

Scoring keys were made for each of the six film movement rates. To make the keys, a test set of imagery was allowed to run through the machine with the frame counter on at each of the six speeds. Since the polygraph ran at the constant rate of 3mm/sec, paper strips of six different lengths were obtained. The target frames were then noted on each strip by colored pencil marks between the proper ink tic marks which delineated the beginning (and end) of each frame. It was a relatively simple matter to score each run against the appropriate scoring key.

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[3] Reaction times to discrete stimuli have been reported in the literature as ranging in values from .23 to .50 second. If one includes other delay times such as latency (at least .1 second) and perceptual span of vision (on the order of .2 second) it appears that a screening rate of .8 sec/frame for 70mm imagery is very close to, and may in some individuals exceed, the psychophysiological limit of response time.

RESULTS

Screening Accuracy

The results of the complete analysis of variance of screening accuracy appear in Table 2. For this analysis of variance, which is based on a large number of degrees of freedom and several variables, the .01 level of significance was adopted as the minimum criterion, to reduce the risk of accepting a difference as being significant when in fact it might not be significant. All F values in Table 2 (except for order, rate x order interaction, triple interaction, and residual error term) are significant beyond the .01 level.

Table 2

Analysis of Variance of Screening Accuracy Scores for the Indicated Variables and Interactions

Source of variation	df	MS	F	P
Rate	5	102.6138	9.1265	.001
Order	3	14.1055	1.2545	--
Rate x order	15	8.0805	.7187	--
e_1	24	11.2435		
Scale	3	449.4319	189.7538	.001
Resolution	3	121.2826	51.2065	.001
Set position	3	22.6784	9.5750	.001
Batch position	3	239.1506	100.9713	.001
Scale x resolution	9	26.3520	11.1260	.001
Rate x scale	15	5.4152	2.2863	.01
Rate x resolution	15	5.3534	2.2602	.01
Rate x period	15	5.5117	2.3271	.01
Rate x batch	15	5.5881	2.3593	.01
Rate x scale x resolution	45	4.1853	1.7671	.05
Residual	234	4.1960	1.7716	.05
e_2	360	2.3685		
Total	767			

The screening accuracy means for rates are shown in Table 3. The dashed underlining in Table 3 indicates those means, as determined by the Newman-Keuls Test, that could have been drawn from a common population of means at the .01 level of confidence. In the initial analysis, the .8 sec/frame rate shows a significantly poorer performance than the other rates. However, further analysis shows that the 1.0 and .8 sec/frame rates are not statistically dissimilar at the .01 level of confidence, thereby indicating the marginal status of the 1.0 sec/frame rate performance score.

Table 3

Screening Accuracy Means for the Indicated Seconds Per Frame

Sec/frame	4.0	6.0	2.0	1.5	1.0	.8
	72.68	72.52	71.24	70.08	66.88	63.64

Note. Dashed underlines group items not significantly different from each other.

The screening accuracy means for scales are presented in Table 4. The Newman-Keuls Test has shown that each of the means in Table 4 is significantly different from the other means. With both large and small scales, direct viewing of moving imagery for screening purposes is shown to be superior to screening the same moving imagery under 2x magnification.

Table 4

Screening Accuracy Means for Large Scale, Small Scale, and Both Scales Under Magnification

L	LM	S	SM
76.96	71.64	66.52	62.92

Table 5 presents the means of screening accuracy scores for the four levels of resolution. According to the Newman-Keuls Test, the means in Table 5 are significantly different from each other except those for resolution levels of 16 inches and 24 inches SRGD. The mean screening accuracy scores for the 16-inch and 24-inch SRGD levels are less than a point apart, and both show significantly poorer screening performance than the two higher levels of resolution. The 8-inch SRGD level is significantly higher than the 12-inch SRGD level.

Table 5

Screening Accuracy Means for the Smallest Resolvable Ground Dimensions of 8 Inches, 12 Inches, 16 Inches, and 24 Inches

8 inches	12 inches	16 inches	24 inches
73.84	69.92	67.32	66.92

Note. Dashed underline groups items not significantly different from each other.

Figures 1 through 4 (one for each scale level) were constructed to illustrate the screening accuracy mean score trends for the several levels of resolution and film movement rate. In these figures, two horizontal lines are added. The lower line shows the chance performance level (50 correct classifications out of the 100 frames classified) that would be expected if the interpreter guessed concerning the target/nontarget nature of each successive frame. The upper line shows the 1% fiducial limit, 61.65 correct classifications per 100 frames. On the average, one interpreter out of 100 interpreters could be expected to obtain a screening accuracy level of 61.5 correct classifications or higher, assuming that all interpreters classified all frames strictly by guessing.

Figures 1 through 4 show that, with some minor fluctuation, there is little loss in screening accuracy scores for a presentation rate of 6.0 to 1.5 sec/frame for large scale and from 6.0 to 2.0 sec/frame for small-scale imagery at all levels of resolution. For all but the highest resolution, performance was better with 1:2,000 scale than with the 1:4,000 scale imagery.

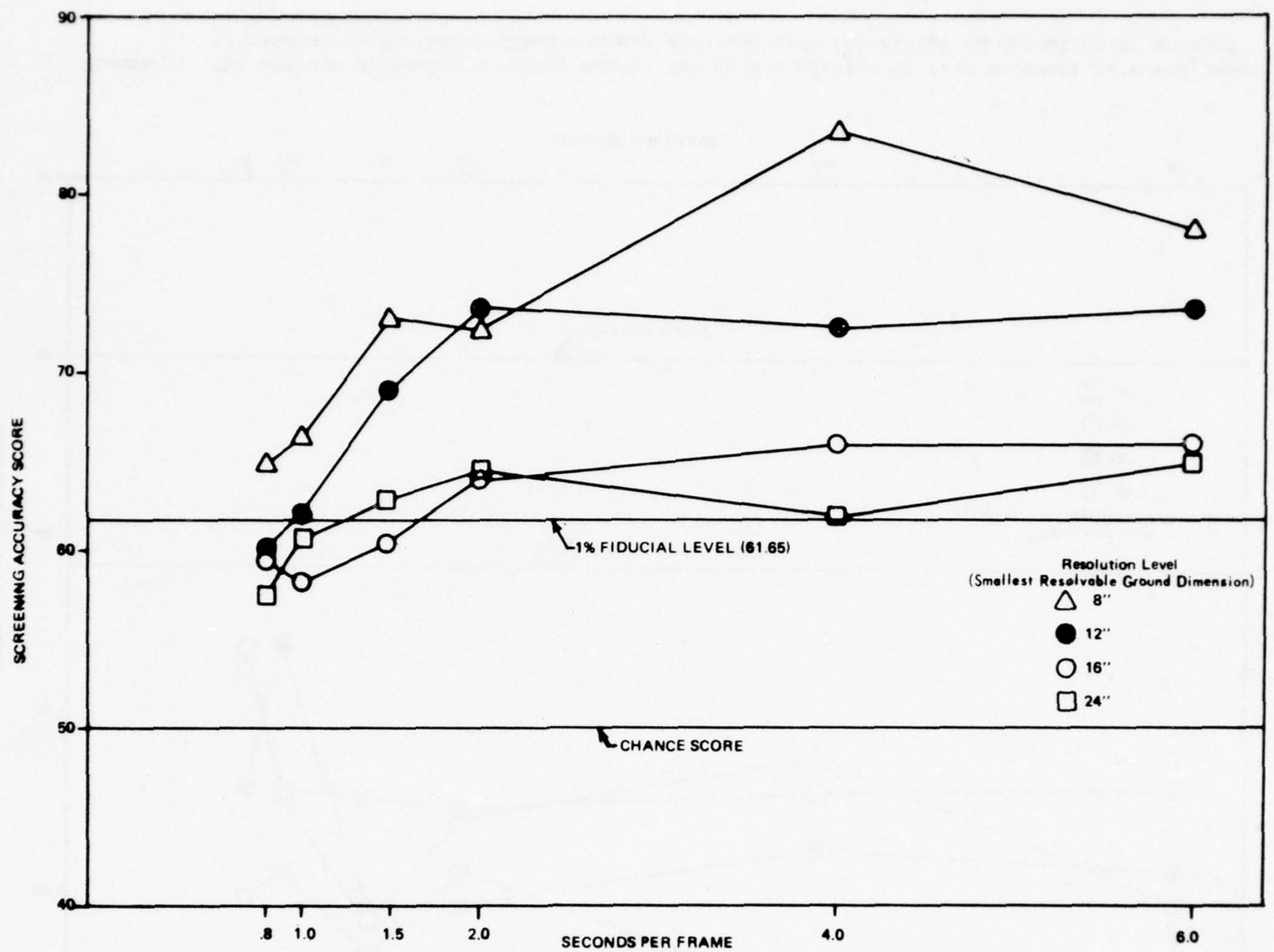

Figure 1. The average screening accuracy scores for each condition of film movement rate and level of resolution for SMALL-SCALE imagery with the task restricted to detection of wheeled or tracked vehicles.

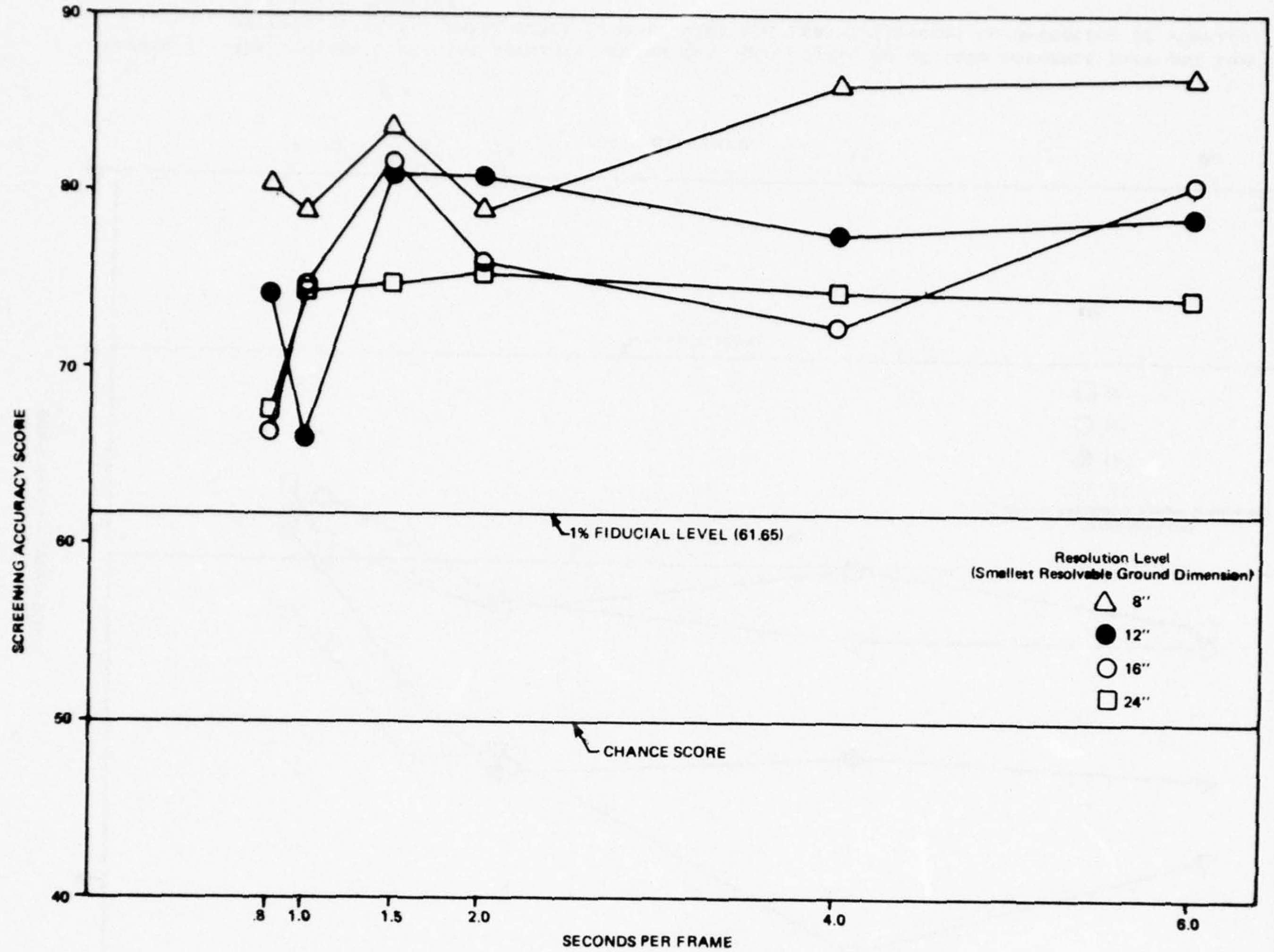

Figure 2. The average screening accuracy scores for each condition of film movement rate and level of resolution for LARGE-SCALE imagery with the task restricted to detection of wheeled or tracked vehicles.

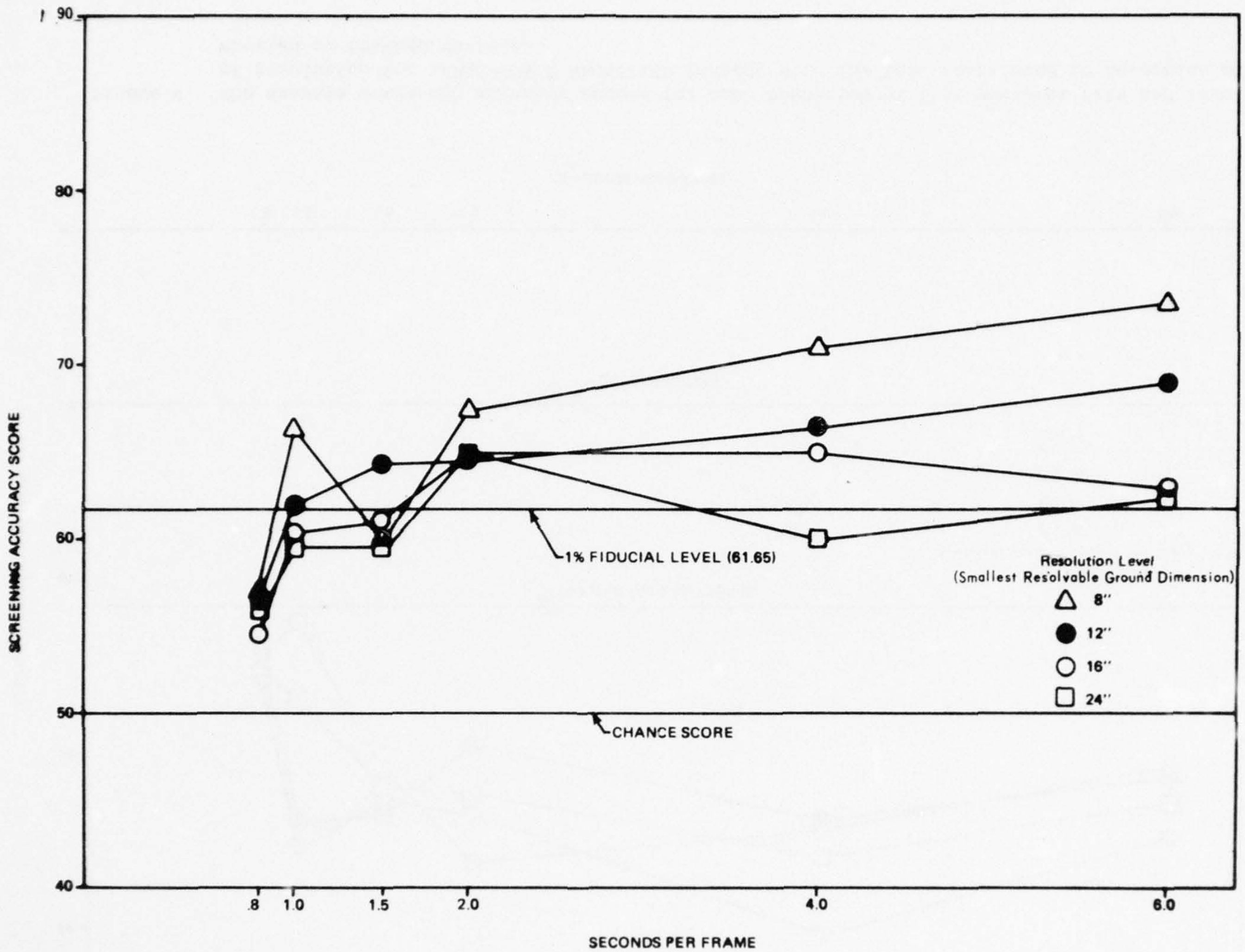

Figure 3. The average screening accuracy scores for each condition of film movement rate and level of resolution for SMALL-SCALE MAGNIFIED imagery with the task restricted to detection of wheeled or tracked vehicles.

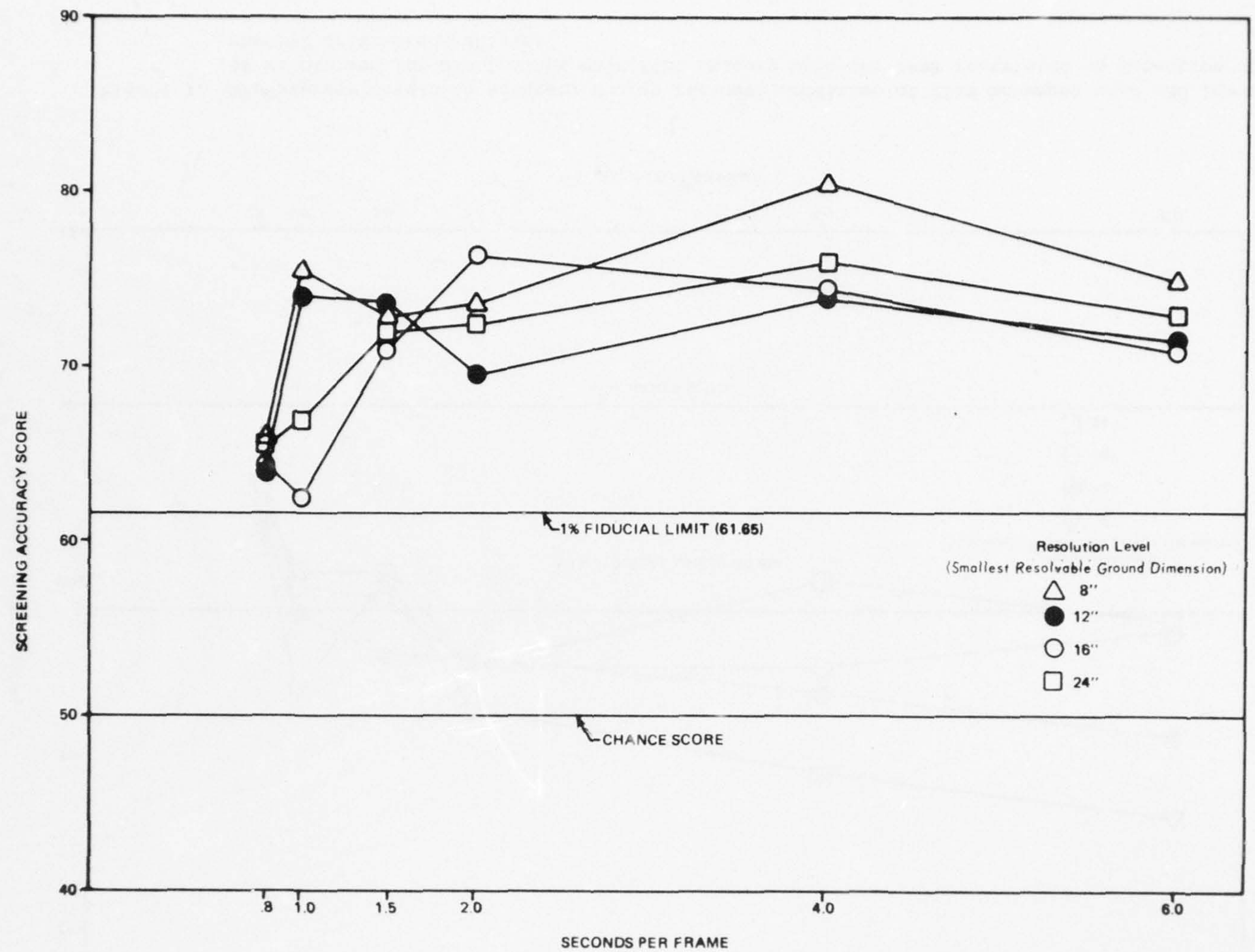

Figure 4. The average screening accuracy scores for each condition of film movement rate and level of resolution for LARGE-SCALE MAGNIFIED imagery with the task restricted to detection of wheeled or tracked vehicles.

Scores for magnified and unmagnified imagery were also compared when the viewing times per unit area of format were the same. Format and target image size appear twice as large in each dimension when viewed under 2x magnification and therefore they seem to be moving more rapidly past the viewer. Consequently, the scores for the unmagnified imagery were compared with magnified imagery having film movement rates four times slower.

Of the six rates used in the study, only four could be used in the comparisons. These were, for each scale: 1.5 sec/frame for unmagnified imagery versus 6.0 sec/frame for magnified image, and 1.0 sec/frame unmagnified versus 4.0 sec/frame magnified.

Magnification of the small-scale imagery offered no significant improvement in screening performance, even though four times the amount of time was allowed to do the task (see Table 6). Each of the means in Table 6 is based on the scores of the examinees that were tested with the given film movement rate. The standard error of the difference between the means is based on an error term obtained through an analysis of variance of the four means.

Table 6

Comparison of Mean Accuracy Scores for Small-Scale Unmagnified (S) and Small-Scale Magnified (SM) Imagery, When Viewing Time Per Unit Area of Format is Constant

Film movement rates	S	SM	t	p
1.5 vs. 6.0	66.36	67.00	.232	--
1.0 vs. 4.0	62.00	65.64	1.319	--

The same kinds of comparisons were made with the large-scale imagery. The mean accuracy scores are shown in Table 7.

Table 7

Comparison of Mean Accuracy Scores for Large-Scale Unmagnified (L) and Large-Scale Magnified (LM) Imagery, When Viewing Time Per Unit Area of Format is Constant

Film movement rates	L	LM	t	p
1.5 vs. 6.0	80.24	72.64	2.61	.05
1.0 vs. 4.0	73.64	76.24	.89	--

The data in Table 7 indicate that magnification of large-scale imagery provided no improvement in screening performance, even though four times the amount of time was allowed to do the task. In fact, viewing the large-scale imagery at 1.5 sec/frame resulted in significantly better performance than viewing the magnified imagery at 6.0 sec/frame.

Screening Thoroughness

The ratio of the number of frames responded to, either correctly or incorrectly, over the total number of frames presented constitutes an individual's screening thoroughness score. The average screening thoroughness scores of the eight examinees tested under the conditions of scale, resolution, and film movement rates are given in Table 8.

Review of Table 8 reveals that the screening thoroughness scores all approach or achieve 100%. Because of this homogeneity, a rigorous statistical analysis of the data was not attempted.

Table 8

The Mean Screening Thoroughness Scores for Each Set of Conditions of Scale, Smallest Resolvable Ground Dimension (SRGD), and Rate (in sec/frame)

	Large scale				Small scale			
SRGD	8"	12"	16"	24"	8"	12"	16"	24"
6.0	100	100	97	100	100	100	99.5	100
4.0	99	100	100	100	100	99.5	99.5	100
2.0	100	100	100	100	100	100	100	100
1.5	100	99.5	100	100	100	100	99	100
1.0	100	98.5	100	98.5	98.5	99.5	99	98.5
.8	99.5	100	100	100	98.5	100	100	99.5
	Large scale, magnified				Small scale, magnified			
	8"	12"	16"	24"	8"	12"	16"	24"
6.0	99	100	100	100	100	99.5	100	100
4.0	100	99.5	100	100	100	99	100	99.5
2.0	100	100	100	99.5	99.5	99.5	100	100
1.5	100	98.5	100	99.5	98.5	100	100	99.5
1.0	98.5	99.5	96	100	100	98.5	99.5	100
.8	99	100	100	99	97.5	99.5	99	98.5

SUMMARY AND IMPLICATIONS OF FINDINGS

The three factors of image resolution, presentation rate, and image scale affected image interpreter screening accuracy of 70mm imagery rolls whose successive frames contained nonoverlapping and noncontiguous terrain, for wheeled or tracked vehicles. Tradeoffs which may be acceptable operationally are possible among these factors.

Image Resolution

Imagery resolution level (smallest resolvable ground dimension, or SRGD) is important because use of lower resolution levels resulted in poorer screening performance.

Presentation Rate

For the type of imagery and task used in this study, within the range of .8-2.0 second viewing time per frame, poor resolution can be compensated for by increasing viewing time per frame. Increasing viewing time per frame beyond 2.0 seconds does not increase screening accuracy.

Image Scale

Increasing the scale of the imagery increased screening accuracy. With a constant display format, in which larger scale imagery covers a proportionately smaller area of terrain, screening accuracy scores were higher when large-scale imagery (1:2,000) was used than when small-scale imagery (1:4,000) of approximately the same resolution was used. This increase in accuracy could be due to displacement of targets toward the center of the display, to elimination of nontarget content from the display, to increased size of targets and nontarget "noise," or to some combination of these factors.

However, doubling the size of the imagery by 2x optical magnification, which increases perceived viewing area without changing resolution or scale, caused a decrease in screening accuracy when viewing times remained the same. When viewing time was increased fourfold to compensate for the increased viewing area, accuracy was the same for magnified and unmagnified imagery.

APPENDIX A

TECHNIQUE USED TO PRODUCE IMAGERY

An extensive search of film libraries maintained by the Army, Navy, and Air Force proved fruitless in that not enough imagery could be found that met all of the criteria for imagery to be used in this study. The most difficult criterion to meet was one calling for imagery with known and consistent resolution. Therefore, it was decided to acquire the imagery first-hand.

With the cooperation of the Commanding Officer, U.S.M.C. Air Station, Quantico, Va., a twin engine C-45 equipped with camera mounts was made available to ARI personnel. Marine Naval Aviators, aerial photographers, and a CA-8, 6-inch focal length, aerial camera were also provided on a mission request basis. (The film for the CA-8 camera system was supplied by USAECOM, Fort Monmouth, N.J).

After obtaining the necessary clearances, preliminary flights were made over local military installations. These installations were Camp A. P. Hill, Va., U.S.M.C. Base, Quantico, Va., Fort Meade, Md., and Fort Belvoir, Va. Of all of these locations, only the latter proved to have the equipment and environment to meet the criteria of a variety of required target types, (both dispersed and clustered) and a number of vegetated and cleared areas. The rest of the criteria could be satisfied by acquiring enough imagery, by film editing and processing, and by providing a means to determine ground resolution.

A tri-bar resolving power target chart was designed and constructed by BESRL personnel. This 16' by 48' chart with a Brightness Ratio (contrast) of approximately 7:1 was spread out on an off-duty runway at Quantico and photographed at the assigned altitude, before and after each photo mission over Fort Belvoir. The widths of the tri-bars were arbitrarily made as follows: 24, 16, 12, 8, 4, 3, 2, 1-3/4, 1-1/2, 1-1/4, 1, 3/4, and 1/2 inches with a length to width ratio of 5:1. As one can see, the expectation was that the smallest resolvable ground dimension (SRGD) would be among the smaller values where the differential between successive steps was small. However, this expectation was not realized. Due to lack of a forward motion compensator in the CA-8 (a camera of Korean War vintage) the smallest resolvable known dimensions on the imagery proved to be the 8-inch tri-bars of the chart when photographed at an altitude of 2,000 feet.

Two photo missions provided enough imagery to meet the requirement for 50 target frames and 50 nontarget frames at 1:4,000 scale. The one-hundred 70mm frames were cut from the CA-8's 9" x 9" imagery format. In this manner greater latitude was possible in selecting the number of targets (or lack of targets), the exclusion of other man-made objects, and the amount of cover. The target frames contained a target density of 1-10 and a range of foliage cover 0% to 99%. The range of foliage

cover for the nontarget frames also was 0% to 99%. Of the total of 113 targets, 22 of them were partly hidden. Six of the 50 target frames contained only partly hidden vehicles accounting for half of the total of 22.

In order to be able to make a somewhat more meaningful comparison between scales, almost all of the targets and their immediate surroundings are identical in both. This was accomplished as follows:

1. One hundred 70mm squares were cut from the second generation positive 9" x 9" imagery at a scale of approximately 1:4,000. Half of the frames contained targets. This comprised the small-scale set. (Note: there was no overlap from frame to frame in this series.)

2. The 70mm square areas were marked off on the first generation negative and these areas were enlarged photographically to produce a second generation positive enlarged to a scale of approximately 1:2,000.

3. The 100 large-scale frames were cropped back to 70mm size retaining almost all of the targets and their surrounding areas. Consideration was also given to the amount of foliage cover so that the large-scale frames closely approximated their small scale counterparts in this respect.

4. The small-scale frames were then shuffled to randomize their order and spliced together. The shuffling resulted in 11 target frames appearing in the first 25 frames, 13 in the second 25, 11 in the third 25, and 15 in the last 25. Black plastic tape was used in the splicing and to make a border at top and bottom leaving a 2-1/4" square imaged area in the center of each frame.

5. The large-scale frames were placed in the same sequence as the small-scale frames and also spliced together.

6. Since smooth imagery without splices was desired for the testing machine, duplicate 4th generation positives were made of each run of 100 frames.

This procedure produced two sets which were almost identical in target content, of the same format size and ground resolution, similar in terrain features and foliage cover, but different in ground area coverage and size of the same imaged targets. An important feature is that the information bits concerning the targets and their immediate surrounding areas are similar in both scales. In this study, resolution refers, not to the resolution of the imagery which is described in terms of lines per mm or line pairs per mm, but rather to the smallest resolvable ground dimension (SRGD). The SRGD, according to the resolution charts, which

were photographed at the beginning and end of each photo mission, is 8 inches. There was no appreciable loss in SRGD from the first to the fourth generation. The latter was used as the highest level of resolution.

To obtain several levels of degraded imagery simulating transmitted imagery at various bandwidths, a systematic procedure was followed. A standard USAF Military Standard 150A resolution chart was calibrated to match the BESRL Tri-bar Resolving Power Chart. The steps in calibration were:

1. The 8" group of tri-bars (small scale imagery) was measured along the long dimension on a Gilliland Point Coordinate Mensurator. The obtained size (average of 3 readings) was 360 microns.

2. Examination of the M. S. 150A resolution chart tri-bars showed Group 3-Element 3, which measured 340 microns, to be closest to the BESRL 8" group.

3. The M. S. 150A chart was enlarged slightly so that Group 3-Element 3 tri-bars measured 360 microns.

4. The enlarged M. S. 150A chart was degraded by defocusing the camera lens to the point where Group 3-Element 3 tri-bars were the smallest set resolvable on the chart. The two charts were then equivalent in resolution and the M. S. 150A with its finer steps between intervals could serve as a better control in the degradation steps to follow.

Frames containing two BESRL charts (one large scale and one small scale) and three degraded (matching) M. S. 150A charts were spliced at each end of both the large scale and small scale imagery as controls. Six successive generations were made using a base to base (opposite of emulsion to emulsion) contact printing technique on a strip printer which used a noncoherent light source. The two intermediate positive generations between the 4th generation positive and the final (10th) generation positive were selected for inclusion in the experiment. Fortuitously, the 6th, 8th, and 10th generation in turn were degraded approximately to the point where the 12, 16, and 24 inch bars, respectively, were just resolvable on the BESRL Tri-bar Resolving Power Chart. The M. S. 150A charts verified these values. Table A-1 shows the appropriate set of the calibrated M. S. 150A Groups and Elements and their associated sizes in inches on the ground.

Table A-1

Selected Groups and Elements for the Enlarged Military Standard 105A Resolution Chart and Their Representative Ground Dimensions

Group	Element	Ground dimensions[a]	
3	3	8.00"	(4th Generation Positive)
3	2	8.98"	
3	1	10.08"	
2	6	11.31"	(6th Generation Positive)
2	5	12.70"	
2	4	14.26"	
2	3	16.00"	(8th Generation Positive)
2	2	17.96"	
2	1	20.16"	
1	6	22.63"	(10th Generation Positive)
1	5	25.40"	
1	4	28.57"	

[a]The elements increase in size by the sixth root of 2.

In this study the lack of a camera with forward motion compensation (IMC) or an extremely fast shutter precluded acquisition of smaller SRGD's--perhaps as small as 1 to 2 inches. Had these higher resolutions been used then a wider range of imagery degradation could have been explored with respect to screening performance. In terms of line pairs per millimeter, imagery resolutions of approximately 10 lp/mm to 1.7 lp/mm were included in the study.

In future work a larger range of resolutions could be studied using the same target types as in this experiment as well as smaller target types such as personnel, foxholes, and gun explacements.

APPENDIX B

GENERAL BACKGROUND

The early detection of targets is almost universally conceded to be of paramount importance in military operations. The most desirable procedure, of course, would be to perform the detection or screening operation in real-time, that is, at the same time as the imagery is being acquired. This, however, is not possible in some instances. One such instance occurs when photographic imagery is used.

The U.S. Army Electronics Command presently is experimenting with the immediate processing of aerial photographs in surveillance aircraft, then electronically transmitting these photographs directly to a ground station or via relay aircraft, and finally reprocessing the signals into photographic imagery. The present state-of-the art requires about 10 seconds for the initial processing after photo acquisition, about 5 seconds transmission time, and about 10 seconds for final processing. At this point the imagery is approximately 25 seconds delayed from real-time. This delay is due entirely to current equipment limitations. The next limitation which will add further delay in photo interpretation is the time taken to visually screen a large amount of imagery to select specific frames for more detailed analysis. Obviously, the shorter the time for screening the nearer to real-time will be the photo interpretation.

This study is expected to determine what screening accuracy and screening thoroughness can be expected for several different rates of moving imagery.

APPENDIX C

TRAINING INSTRUCTIONS

During this training run and for the test run which will come later on the other machine, you will screen each frame of imagery for wheeled and/or tracked vehicles. Specifically, you will screen for tanks, trailers, trucks, bulldozers, cranes, front loaders, shovels, and automobiles. The presence of at least one vehicle is sufficient to identify that particular frame as a target frame.

This run is simply a preliminary exercise to train you how to indicate which frames are target frames and which are not. This particular set of imagery was selected so that frames with targets are quite obvious as are those without targets. The important thing at this time is to learn <u>when</u> to indicate your decision as to the presence or absence of targets in any given frame.

To respond to a given frame, use the switch on the right leg of the device. This switch has three positions: middle (neutral), left (reject-no-target) and right (accept-target). All you need do is respond once per frame--either reject or accept. <u>Be sure to respond to every frame containing imagery</u>--do not respond to blank frames.

Now look into the viewing opening--you will see a green vertical stripe on the left side of the frame mask. The imagery will be moving from right to left. <u>You may respond to a given frame any time any part of that frame is behind the edge of the green stripe</u>. Thus, if you see a target just as a frame comes into view on the right side you must wait until some part of this frame is behind the green stripe before you respond. If you respond either too soon or too late, a red light will go on to let you know that you have responded to the wrong frame.

If the red light goes on even when you waited for the frame to get behind the stripe, it means you have misinterpreted the frame. Don't worry about the mistakes, as these are not being scored. Remember the primary purpose of this short session is to train you to respond at the proper time.

You may go through this run as many times as you wish.

Are there any questions?

APPENDIX D

EXPERIMENTAL RUN INSTRUCTIONS

You will screen each frame for targets, which shall be defined as vehicles, specifically, tanks trailers, trucks, bulldozers, cranes, front loaders, shovels, and automobiles. The presence of at least one vehicle is sufficient to identify that particular frame as a target frame. Respond to every frame, i.e., "target or no target," and respond only once per frame.

You will respond to the frames in exactly the same way you just did on the training device. The switch on the right leg of this device works the same as the other, i.e., middle (neutral), left (reject-no-target), and right (accept-target). You may respond to a given frame any time any part of that frame is behind the edge of the green stripe.

These runs will differ from the last in three respects. First, there will be no blank frames. Second, there will be no red light. Third, you will see imagery at a number of different resolutions so you can expect to see marked changes in image quality from time to time.

Are there any questions?

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